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BRIDGES AND ACCESSORIES

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Electro Scientific Industries

13900 N.W. SCIENCE PARK DRIVE • PORTLAND, OREGON 97229

SEPTEMBER 1966

MODEL

232A

Instruction Manual

GUARDED WHEATSTONE RESISTANCE MEASURING SYSTEM

CONTROLLED DOCUMENT

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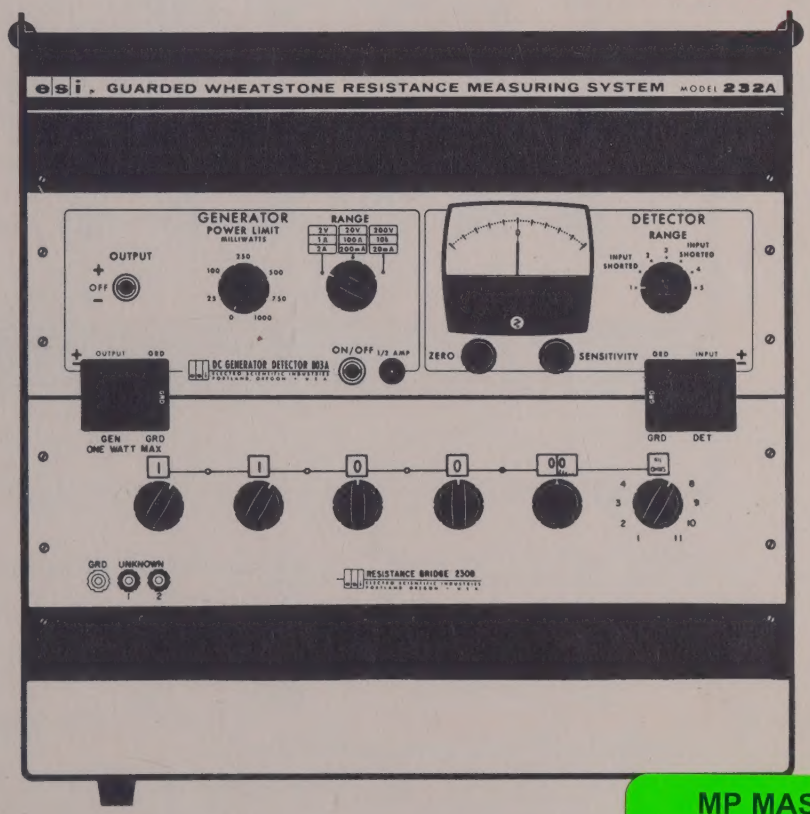

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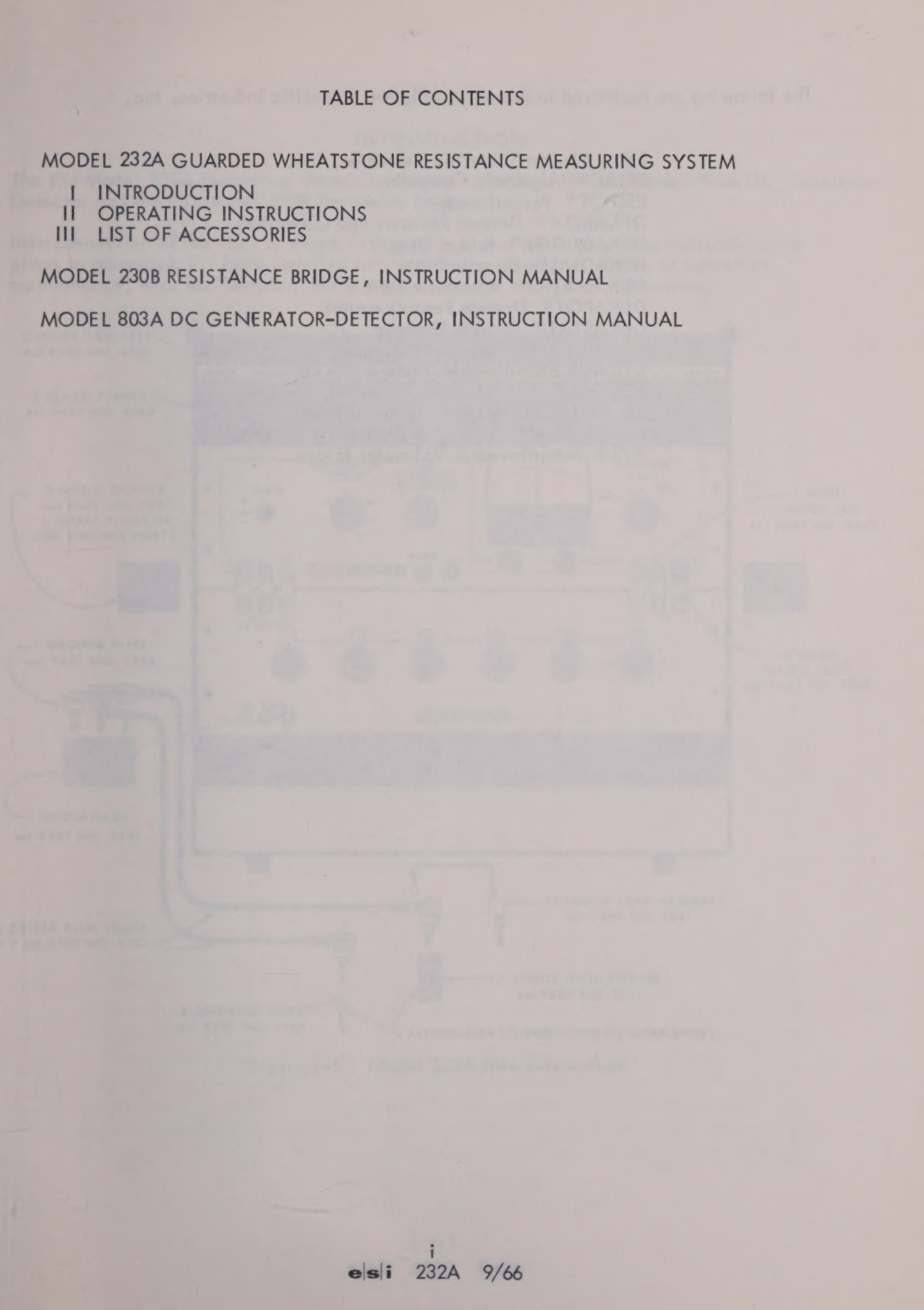

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SECTION I

INTRODUCTION

The ESI Model 232A Resistance Measuring System consists of the ESI Model 803A DC Generator-Detector and the ESI Model 230B Resistance Bridge.

Interconnection of the units is shown in Figure 1-1, and basic operating instructions are given in paragraph 2. More detailed instructions for operation, theory of operation, maintenance, etc. are included in the manuals for the individual instruments.

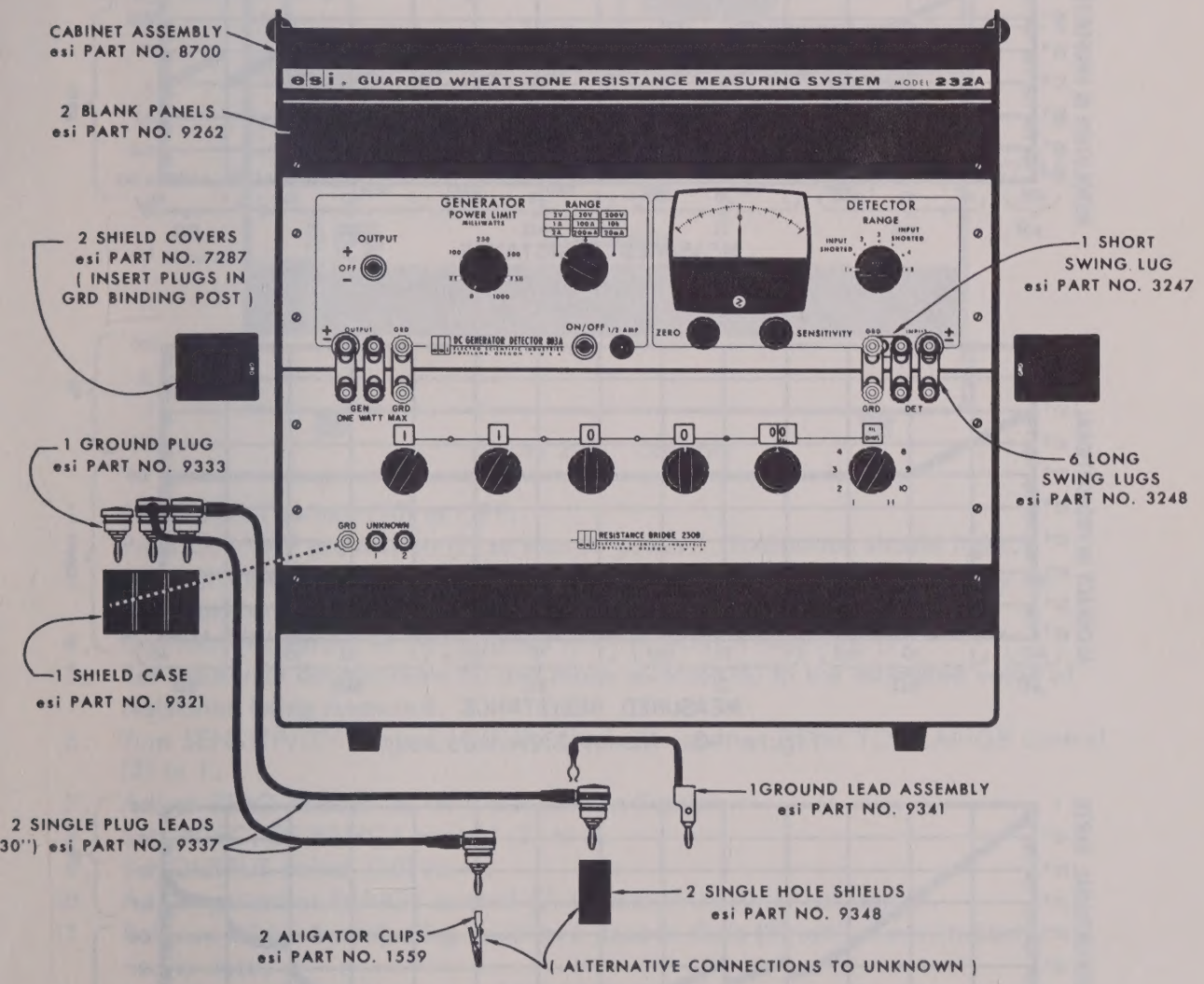


Figure 1-1. Model 232A Interconnection

Specifications for the Model 232A Resistance Measuring System are summarized in Figures 1-2, 1-3, and 1-4. The resolution, accuracy, and sensitivity are shown in proportional parts (as well as parts per million and percent) of the measured resistance. Resolution and accuracy shown are characteristics of the Model 230B Resistance Bridge with any generator and detector. Sensitivity shown is at maximum generator power and detector sensitivity of the Model 803A Generator-Detector.

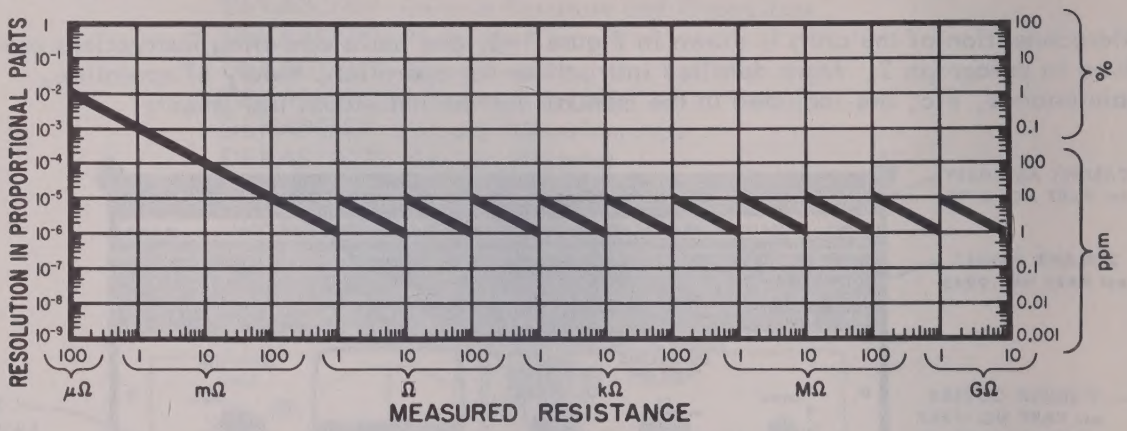


Figure 1-2. Model 232A Resolution

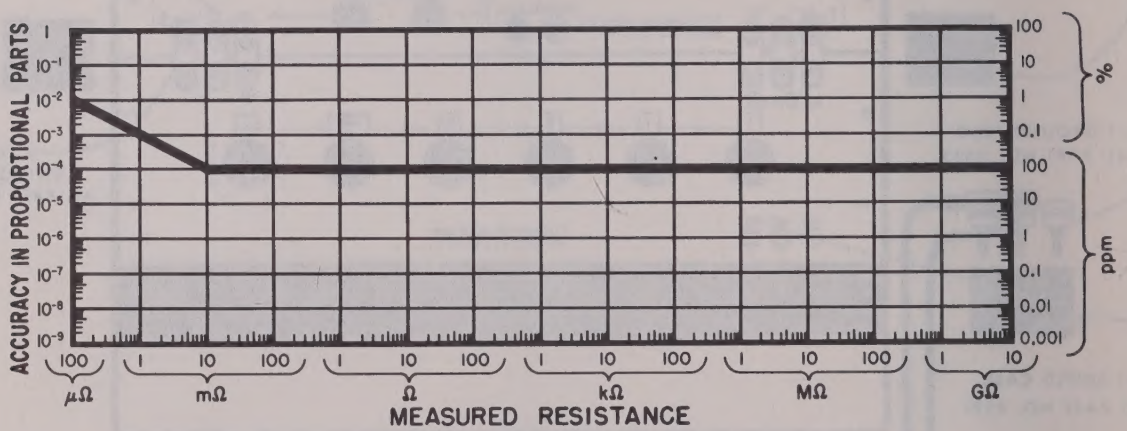


Figure 1-3. Model 232A Accuracy

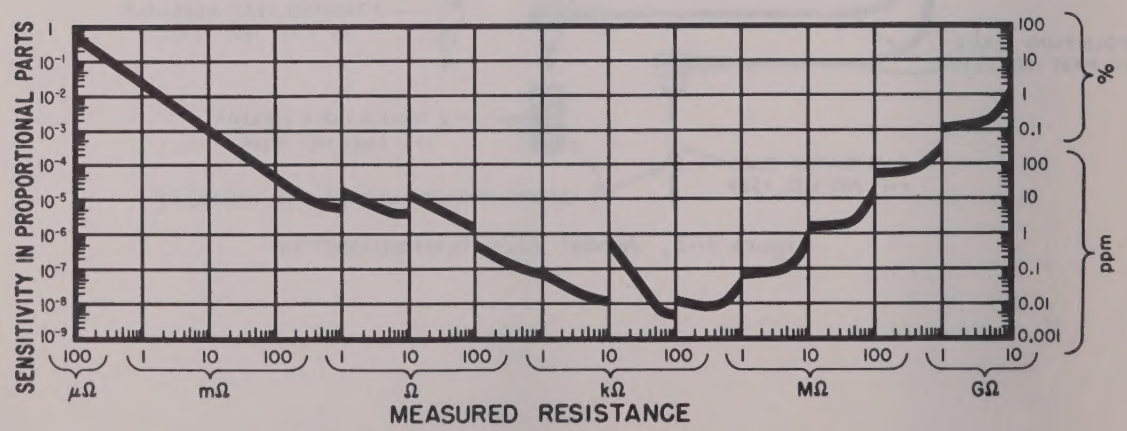


Figure 1-4. Model 232A Sensitivity

SECTION II

OPERATING INSTRUCTIONS

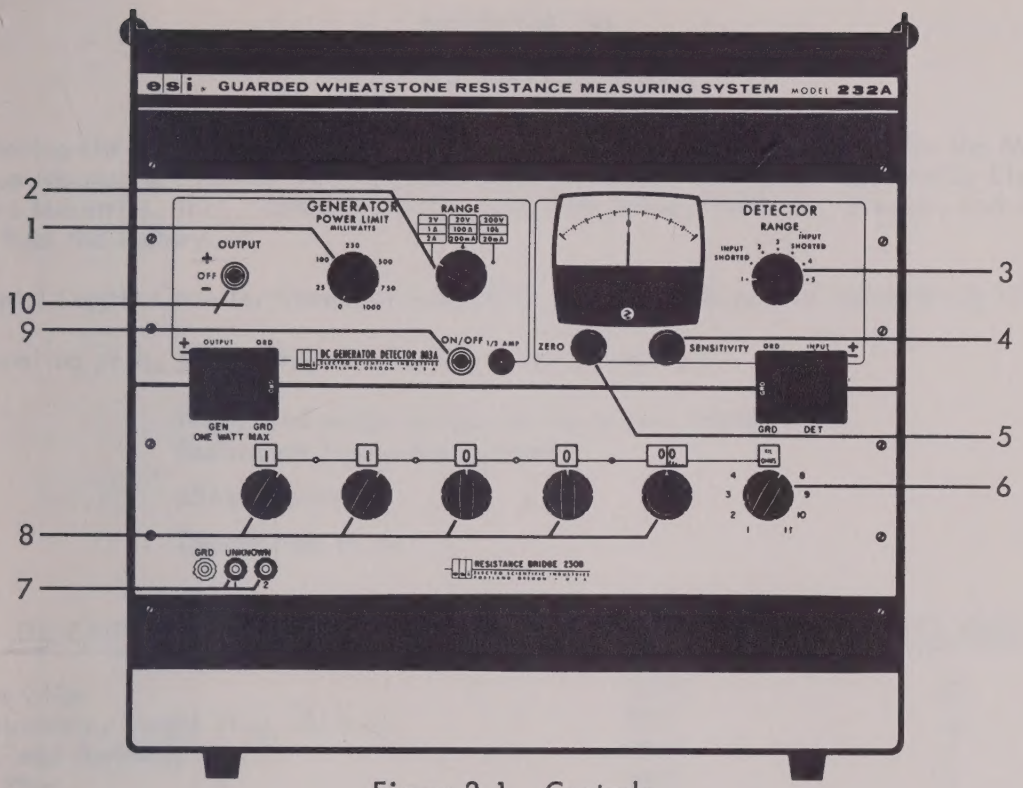
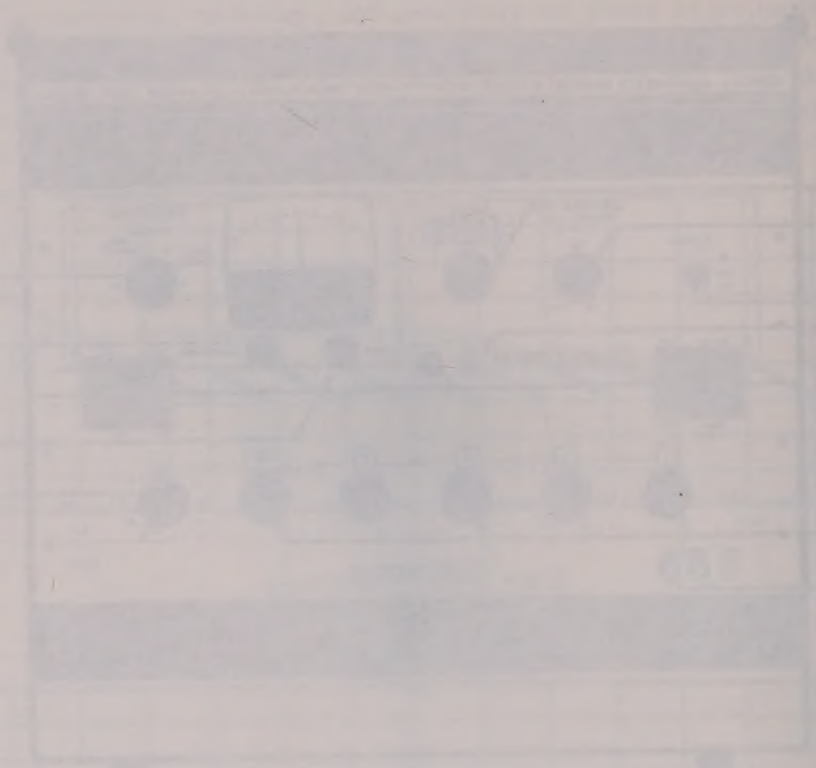


Figure 2-1. Controls

1. Set OUTPUT switch (10) to OFF.
2. Press ON/OFF pushbutton (9) to turn on power. (Pushbutton should light.)
3. Set GENERATOR POWER LIMIT control (1) to 250 MILLIWATTS. (It may be necessary to increase power when making some measurements.)
4. Connect the resistor to be measured to UNKNOWN terminals (7).
5. Set resistance decade dials (8) and range selector (6) to the estimated value of resistance being measured.
6. Turn SENSITIVITY control (4) fully clockwise and set DETECTOR RANGE control (3) to 1.
7. Adjust ZERO control (5) for meter zero indication.
8. Set DETECTOR RANGE control (3) to 5.
9. Set OUTPUT switch (10) to + .
10. Adjust generator RANGE control (2) for maximum meter deflection.
11. Balance bridge by adjusting resistance decade dials (8) until meter indicates nearly zero.
12. Increase sensitivity by turning DETECTOR RANGE control (3) counterclockwise slowly one step at a time until meter indication is slightly less than full scale.
13. Repeat steps 11 and 12 until the bridge is balanced with sufficient accuracy.
14. Set OUTPUT switch (10) to OFF and readjust ZERO control (5) for meter zero indication. If adjustment is necessary, set OUTPUT switch (10) to + and repeat step 11.
15. Read value of unknown resistor from resistance decade dials (8).



SECTION III

LIST OF ACCESSORIES

The following list of items are in the interconnection kit (ESI Part No. 7283) for the Model 232A Resistance Measuring System. All items listed are manufactured and/or supplied by Electro Scientific Industries, Inc., 13900 N.W. Science Park Drive, Portland, Oregon, and may be ordered from the factory.

The Federal Supply Code for Manufacturers (FSC) for Electro Scientific Industries is 11837.

When ordering parts, please include the following information;

Name and model number of the system (Model 232A Resistance Measuring System)

ESI part number

Description of part

DESCRIPTION	PART NO.	QTY USED
Alligator Clips	1559	2
Cable Assembly, Single Plug, 30 inch.	9337	2
Ground Lead Assembly	9341	1
Ground Plug	9333	1
Instruction Manual	7282	1
Shield Case, 1-Hole	9348	2
Shield Case, 3-Hole	9321	1
Shield Covers	7287	2
Swing Lug, Long	3248	6
Swing Lug, Short	3247	1

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BRIDGES
AND
ACCESSORIES

JUNE 1964

MODEL

230B

Instruction Manual

RESISTANCE BRIDGE

SERIAL NUMBER:_____

PART NUMBER: 7344

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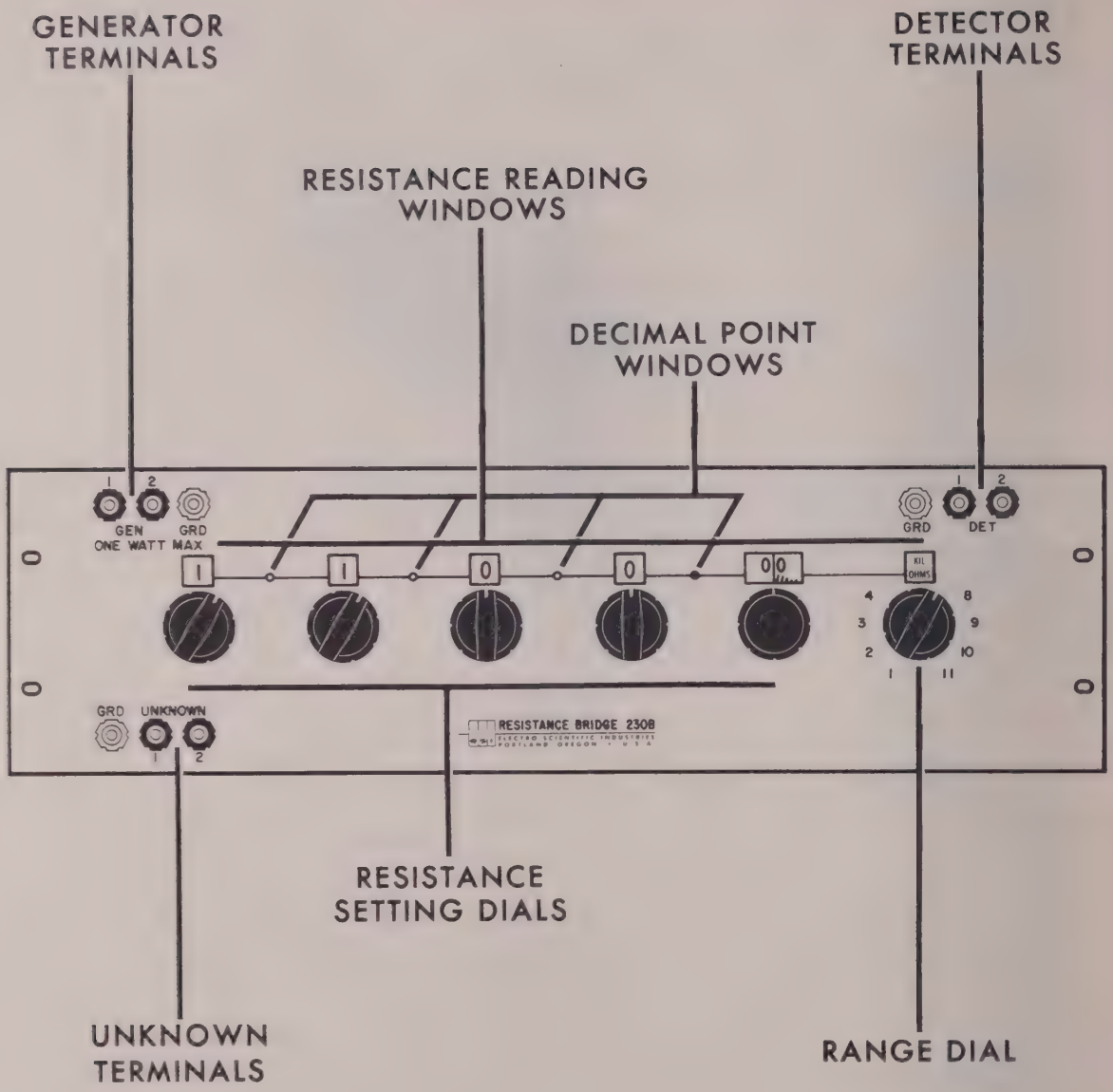
SECTION I
INTRODUCTION

1.1 DESCRIPTION

The Model 230B RESISTANCE BRIDGE is an extremely accurate, high resolution, guarded Wheatstone bridge. The bridge will measure a continuous range of resistance values between 0 and 12 gigohms (12,000 megohms) with a resulution of 1 microhm per dial division on the lowest range. A six-place direct readout combined with eleven ranges enables the operator to make leakage resistance measurements in thousands of megohms or contact resistance measurements in milliohms with equal ease. The internal switching and interconnection circuit is arranged to eliminate sources of error found in many conventional Wheatstone bridge circuits. See THEORY OF OPERATION, Section III.

1.2 SPECIFICATIONS

Resistance Range:	0 to 12 gigohms in eleven ranges (10 microhms per dial division on lowest range).
Accuracy:	±0.01% or ±1 dial division whichever is greater, when corrected for short circuit resistance.
Resolution:	Four decade switches and a 105 division, interpolating rheostat provide 1,200,000 dial divisions of resolution.
Resistance Presentation:	The resistance value appears in windows in a straight line across the panel. The unit of measurement (milliohms, ohms, kilohms, megohms, gigohms) appears beside the value and the decimal point is automatically placed in its proper location.



MODEL 230B RESISTANCE BRIDGE CONTROLS

SECTION II
OPERATION

2.1 CONTROLS AND TERMINALS

RANGE DIAL: The right hand knob selects from eleven ratios, places the unit used in the window and locates the decimal point in the appropriate position for accurate and convenient readout.

RESISTANCE SETTING DIALS: The other four knobs are used to balance the bridge to the value of the resistor under test. The straight line arrangement of the knobs permits operation without visual attention.

RESISTANCE READING WINDOWS: The windows across the top of the bridge present an in-line resistance value indication.

DECIMAL POINT WINDOWS: A reflective backing highlights the correct decimal window determined by the position of the RANGE DIAL.

GEN TERMINALS: The upper left-hand terminals of the bridge are for attaching an external generator. An adjacent ground terminal is provided.

DET TERMINALS: The upper right-hand terminals of the bridge are for attaching an external detector. An adjacent ground terminal is provided.

UNKNOWN TERMINALS: The lower left-hand terminals of the bridge are for attaching the unknown resistor. An adjacent ground terminal is provided.

2.2 AUXILIARY EQUIPMENT REQUIRED

2.2.1 GENERAL

A dc power source and a dc detector for observing a null balance are necessary to operate the bridge. Either the power source or detector may be grounded but the other must be well insulated from ground. Effective leakage resistance to ground from the terminals of either an ungrounded power source or an ungrounded detector should be greater than 10^{10} ohms to avoid bridge errors. See THEORY OF OPERATION, Section III, concerning details on guarding the power source and detector circuits.

The ESI MODEL 800 DC GENERATOR-DETECTOR is recommended to obtain full accuracy over all ranges of the bridge. The ESI MODEL 840 DC GENERATOR-DETECTOR is recommended when full accuracy is not required over the entire range of the bridge. With either of these units all requirements mentioned in this section are met. Write for additional information on these units.

2.2.2 GENERATOR REQUIREMENTS

A large part of the power supplied to the bridge generator (GEN) terminals can be concentrated in one or another of the bridge resistors. To protect the accuracy and stability of the bridge, this power should be limited to a maximum of 1 watt unless a careful analysis is made of where the power will be dissipated. This is accomplished by placing a resistor in series with the power source. The value of this current limiting resistor can be determined by the following formula:

$$R_L = \frac{E^2}{4}$$

where:

R_L = the value of the current limiting resistor

E = the open circuit voltage of the power source

Since bridge sensitivity is directly proportional to the power supplied to the bridge, it is desirable to provide several voltage-resistance combinations to approximately match the bridge input resistance which can be 1 ohm to 100 kilohms depending on the bridge range being used. The following table gives three voltage-resistance combinations which will provide satisfactory performance over the entire bridge operating range:

BRIDGE RANGE	GEN. E.	LIMITING RESISTOR	
0 to 120 ohms	6 volts	10 ohms	5 Watts
120 ohms to 10 megohms	90 volts	2.2k	5 Watts
10 megohms to 12 gigohms	300 volts	25k	5 Watts

If a supply with several voltage-resistance combinations is available it is possible to quickly switch through the available combinations without concern of damage to the bridge or unknown resistor. This then allows you to select the optimum combination for maximum sensitivity. It will, in fact, be the combination that gives the greatest deflection on the detector for a particular bridge unbalance.

The generator section of both the ESI 800 and the 840 is internally limited to one watt and no external resistor is required. However, ALWAYS USE A CURRENT LIMITING RESISTOR IN SERIES WITH ANY POWER SOURCE THAT DOES NOT HAVE INTERNAL LIMITING.

2.2.3 DETECTOR REQUIREMENTS

The output impedance of the Model 230A Resistance Bridge is approximately 100 kilohms. A detector designed to operate from a source of 100 kilohms will yield optimum performance. However, a ten to one mismatch in either direction will not seriously impair sensitivity. A detector with sufficient sensitivity that 10 microvolts at 1 nanoamp is discernible will permit measurements from 0 to 10 megohms at rated accuracy while 3 picoamps and 0.3 microvolts are required for maximum resolution to 12 gigohms.

2.3 MEASURING RESISTORS

1) Connect the external dc generator and detector to the bridge GEN and DET terminals as shown in Fig. 2.2.

WARNING: Limit the generator output to one watt maximum. The ESI Model 800 and 840 feature internal power limiting.

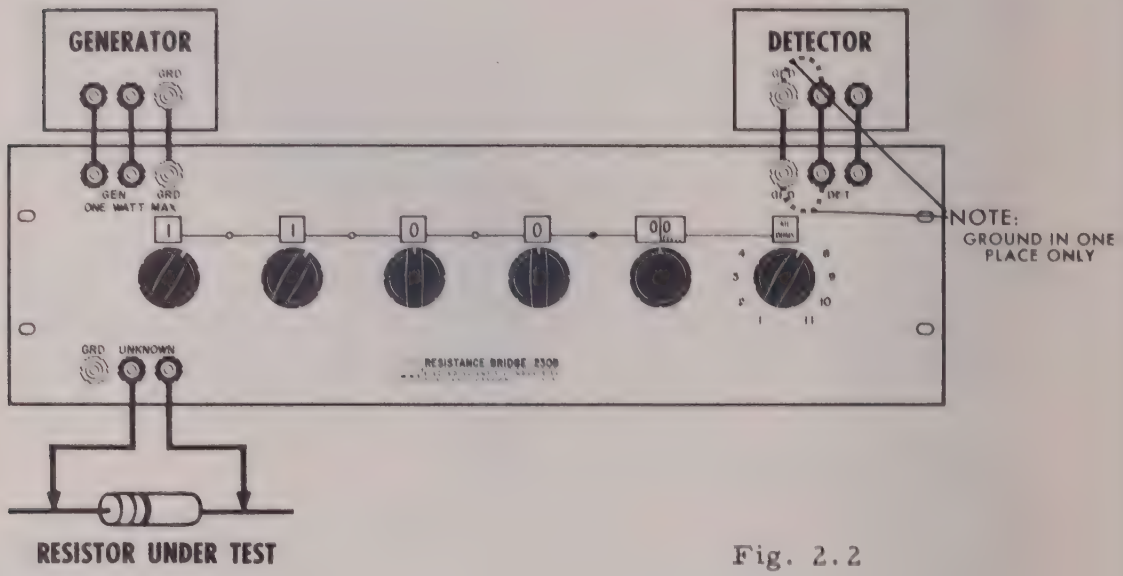


Fig. 2.2

2) Connect the resistor under test to the UNKNOWN terminals.

Make good contact with the terminals. (If the resistor under test is grounded refer to Par. 2.3.1 GROUNDED RESISTANCE MEASUREMENTS.)

3) Set the resistance dials to the nominal value of the resistor under test.

If the nominal value is an even power of ten set the dials to all nines. From this you can go to lesser values, or by use of the TEN position on the dials increase it without disturbing the higher valued decades.

4) Turn on the generator.

Be sure input power is always limited to one watt.

5) Balance the bridge to a null.

The resistance dials indicate, complete with decimal point

and unit, the value of the resistor under test to ± (0.01% + one dial div).

6) Check the null by turning off the generator and noting any change in the detector reading.

Do not disturb the detector or unknown connections for it is necessary that any thermal or electrolic voltages present in the measuring circuit be included in this check. If the detector reading changes from the point to which it was balanced note the new null point (or if preferred the detector may be reset to zero), turn on the generator and rebalance the bridge to this point (or zero).

If an approximate value for the resistor under test is not known, the following outlines an expedient way of precisely determining its value:

Set the range dial to the lowest range and the resistance dials to 1.00000. Rotate the range dial until the null is passed and then switch back one position. Rotate the first resistance dial clockwise until the null is passed and then switch back one position. Repeat this for the second, third and fourth resistance dials. Then adjust the rheostat for a precise null.

2.3.1 MEASURING GROUNDED RESISTORS

The 230B RESISTANCE BRIDGE utilizes a guard chassis which is insulated from the case. This feature allows grounded resistance measurements to be made without affecting the internal guarding qualities of the bridge. Proceed as follows:

1) Connect the ground end of the resistor under test to the UNKNOWN 1 terminal of the bridge.

This places DET 2 terminal at ground potential. If a grounded detector such as the ESI MODEL 800 or 840 is used, it will be necessary to transpose the connections so that the grounded terminal of the detector is connected to the bridge DET 2 terminal. (See Fig. 2.3).

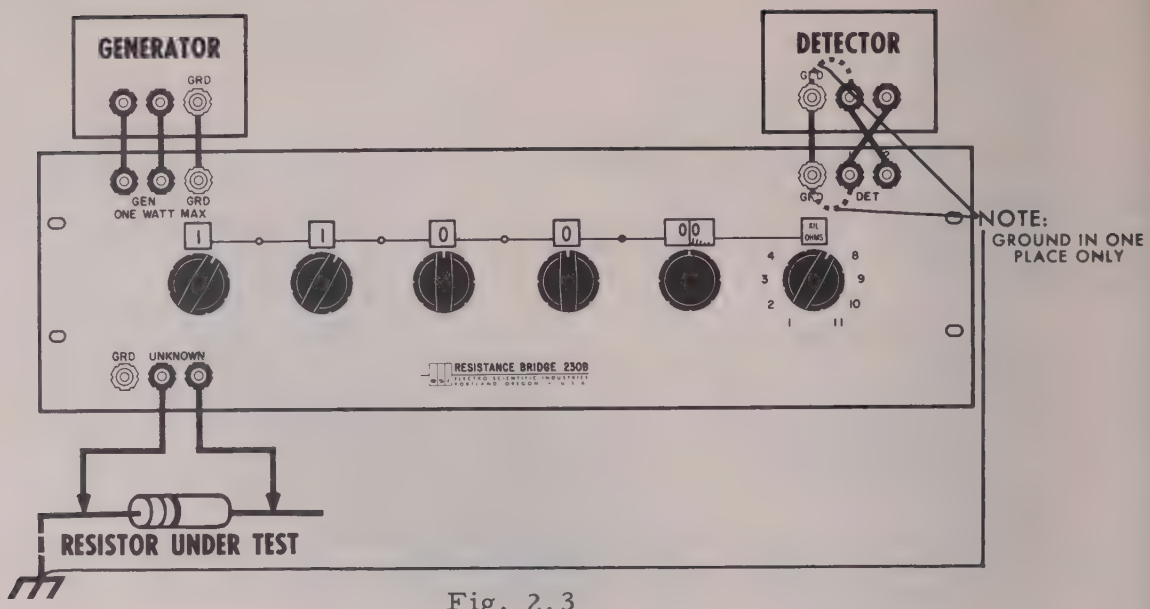


Fig. 2.3

2) Measure the resistor. Proceed as in paragraph 2.3 MEASURING RESISTORS.

2.3.2 HIGH RESISTANCE MEASUREMENTS

The 230B RESISTANCE BRIDGE will measure resistances to 12 gigohms with rated accuracy. However, measurements in this range will require a sensitive detector with a long time constant and low internal noise. Also, a power-limited generator capable of providing the maximum allowable bridge voltage should be used (see paragraph 2.2.1 and 2.2.2 GENERATOR AND DETECTOR REQUIREMENTS).

The bridge guard circuit eliminates internal leakage effects even in the 12 gigohm measurement range. However, it is necessary that the resistor under test is not subject to external leakage effects. When a resistor is mounted between two terminals on an insulating block, the leakage resistance through the block shunts the resistor. When separate insulators are mounted on a conducting support, however, as illustrated in Figure 2.4, the leakages are separated from the resistor. A high value resistor can be mounted in a case using separate insulators as in

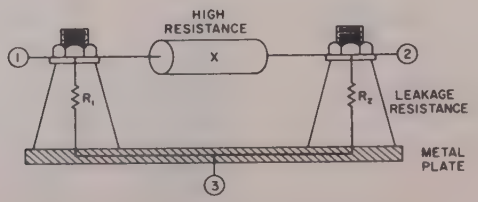


Fig. 2.4

Figure 2.4 so that the insulator leakages can be separated from the resistor value during measurement. When the third terminal (the case or mounting plate) is connected to a Wheatstone bridge as in Figure 2.5, the leakages are placed across other arms of

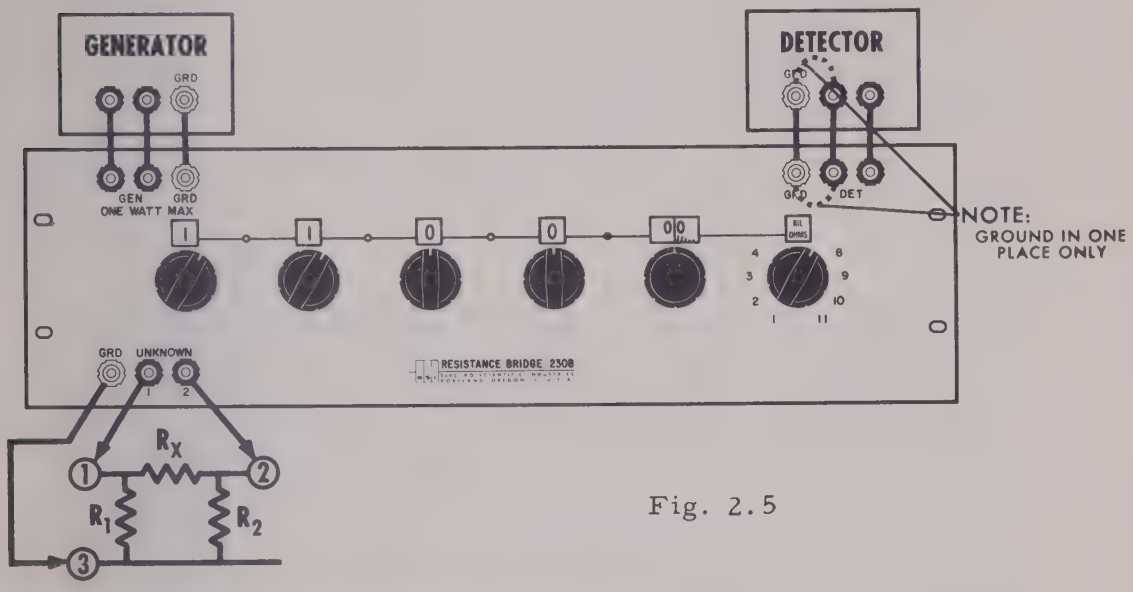


Fig. 2.5

the bridge circuit. Leakage resistance R_1 is across the detector and will cause no error. Leakage resistance R_2 can be across a 100 kilohm bridge arm. With good insulation materials, however, the resistance of R_2 can be made to exceed 10^{10} ohms and it may be neglected. If R_2 is less than 10^{10} ohms, its effect should be determined and corrected for if necessary.

To make three terminal measurements with the 230B proceed as follows:

1)	Ground DET 1	If the detector used is not internally grounded connect a strap between DET 1 and GRD.
2)	Connect (1) and (2) to the UNKNOWN terminals.	See Fig. 2.5.
3)	Connect (3) to the GRD terminal	This completes the necessary bridge connections.
4)	Measure the resistance	Proceed as in paragraph 2.3 MEASURING RESISTORS.

NOTE

Where it is necessary to use connecting leads to measure a high value resistor, it is advisable to use shielded leads and ground the shields. This not only prevents leakage between the leads from appearing in shunt with the resistor under test, it also reduces ac pickup which may be a problem when an electronic detector is used.

2.3.3 LOW RESISTANCE MEASUREMENTS

On the lower ranges of the 230B RESISTANCE BRIDGE the resistance of leads and connectors used to attach the resistor under test to the bridge can be significant. A correction for this "zero resistance" can be made as follows:

1) Connect the resistor under test to the bridge and measure the "unknown resistance".	Proceed as in paragraph 2.3 MEASURING RESISTORS.
2) Short the test leads together at the point they connect to the resistor under test and measure this "zero resistance". The range dial should not be changed from its position in step 1 above.	If test leads are not used the "zero resistance" can be determined by measuring a heavy copper strap or wire connected between the UNKNOWN 1 and 2 terminals. This "zero resistance" should be less than one milliohm.
3) The value of the resistor under test is then the "unknown resistance" minus the zero resistance.	

Four terminal connections have been made directly at the UNKNOWN terminals of the bridge to reduce the resistance in series with the resistor under test. By bringing four leads out from the bridge these junction points can be moved onto the resistor being measured. This four terminal connection places the stray resistances in series with the generator, detector and two of the bridge arms. The resistances in series with the generator and detector will not affect the accuracy of the measurement, but resistance in series with the bridge arm, must be considered. The critical arm is the range resistor for when operating the bridge at 10 or above

on the first decade of the resistance reading arm, this resistor will be less than or equal to the resistor under test. This condition can be avoided through some loss in resolution by switching to a higher range.

One very useful application of the four-terminal measurement is for rapid measurement of very low resistances (one milliohm or less), where accuracy is not too important. Where accuracy and speed of measurement are both important, it is possible to shunt the range resistor to compensate for the stray resistance in series with it. To do this on the lowest range, connect to a one ohm four-terminal standard resistor (increase the standard by a multiple of ten for each increase in range setting), set the resistance dials to the value of the standard and balance the bridge by adjusting the shunt across the one ohm range resistor. The shunt can conveniently be connected between the GEN 2 and DET 2 terminals of the bridge. The bridge will then be calibrated to read the resistor under test directly, as long as the test leads and range dial remain unchanged.

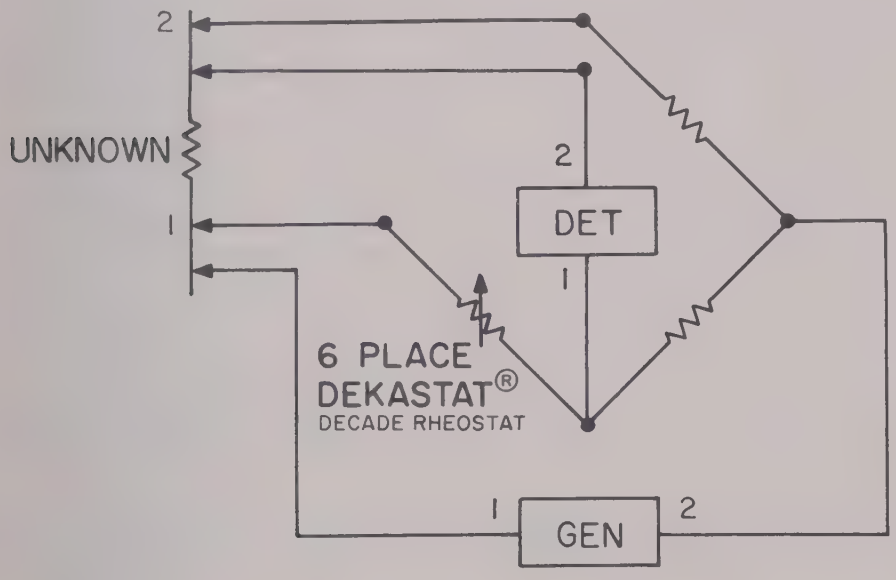


Fig. 2.6

Four terminal resistance measurements using the ESI MODEL 230B RESISTANCE BRIDGE can be made in the following manner:

1) Disconnect the generator from the bridge terminal GEN 1 — The other side of the generator remains connected to GEN 2

2)	Connect this end of the generator to one end of the resistor being measured.	Any resistance in series with this connection will be in series with the generator and will not affect the accuracy of the measurement.
3)	Connect UNKNOWN 2 to this same end of the resistor being measured.	Any resistance in series with this connection will be in series with the 6 place DEKASTAT® (resistance readout arm). This will be a resistance of 10 kilohms per step on the first decade and down by a factor of 10 from this for each succeeding decade.
4)	Disconnect the detector from bridge terminal DET 2.	The other end of the detector remains connected to DET 1.
5)	Connect this end of the detector to the other end of the resistor to be measured.	Any resistance in series with this connection will be in series with the detector and will not affect the accuracy of the measurement.
6)	Connect UNKNOWN 1 to this same end of the resistor to be measured.	The resistance in series with this connection will be in series with one of the ratio arms of the bridge. On the lowest range of the bridge, this arm will only be one ohm and will be increased by a factor of ten for each increased step of the range switch.

2.3.4 HIGH-ACCURACY FOUR-TERMINAL RESISTANCE MEASUREMENTS

The accuracy of the four-terminal measurement procedure of Section 2.3.3, even with range resistor compensation by shunting, is limited by the uncertain reproducibility of the connection resistance which appears in series with the range resistor. This accuracy limitation can be overcome by using a procedure in which two measurements are made and the accurate four-terminal resistance value calculated.

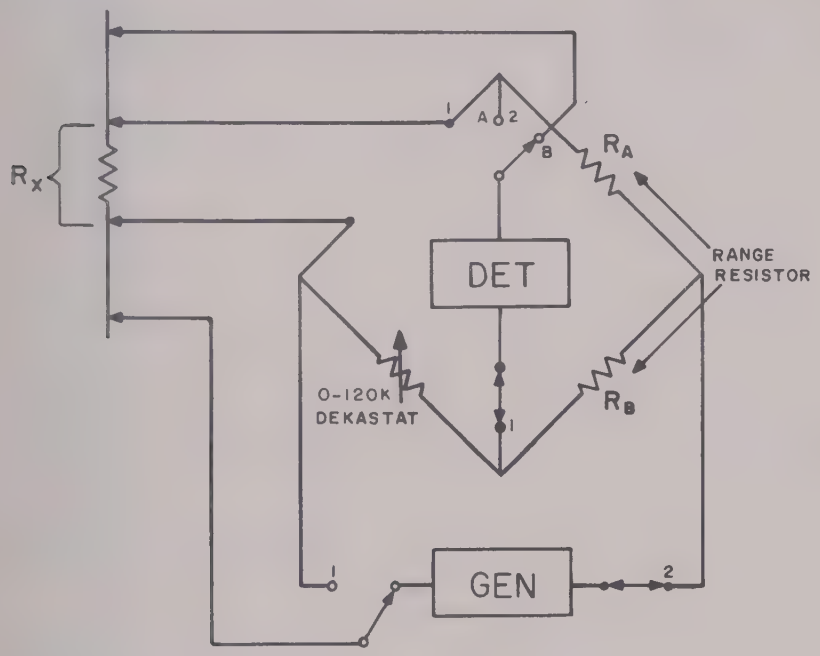


Fig. 2.7

High-accuracy four-terminal resistance measurements using the ESI MODEL 230B RESISTANCE BRIDGE can be made in the following manner:

1) Disconnect the generator from the bridge terminal GEN 1. The other side of the generator remains connected to GEN 2.

2) Connect two test leads to one end of the resistor to be measured; connect one of them to the UNKNOWN 2 terminal and the other to the generator terminal which was disconnected from the GEN 1 terminal.

Resistance in the generator lead will not affect the bridge reading; the lead resistance to UNKNOWN 2 can normally be neglected, since one ohm will cause a change in reading of only one dial division.

3) Connect two test leads to the other end of the resistor to be measured, connect one of them to the UNKNOWN 1 terminal and place the end of the other one near the detector input but do not connect it yet - leave the detector connected to DET1 and 2 in the normal manner.

This connection places the UNKNOWN 1 lead resistance in series with the unknown resistor.

4) Balance and read the bridge; call this reading R_1.

5) Disconnect the detector input lead from DET 2 and connect it to the test lead placed near it in step (3).

This connection places the UNKNOWN 1 lead resistance in series with the bridge range resistor. Take care that the UNKNOWN 1 lead resistance is not disturbed.

6) Balance and read the bridge; call this reading R_2.

Use the same bridge range used for reading R_1.

7) Note the value of the range resistor R_A for the range used.

Its value is the power of ten which is almost equal to full scale on that bridge range.

8) Calculate the unknown resistor value R_x from either of the following formulas:

$$R_x = R_2 \frac{R_A + R_1}{R_A + R_2}$$

For use with desk calculator.

or $$R_x = R_1 - \frac{(R_1 - R_2)}{1 + \frac{R_2}{R_A}}$$

For use with slide rule if $(R_1 - R_2)$ is small enough to have only three significant figures.

SECTION III
THEORY

3.1 GENERAL

This bridge has been designed so that the maximum resistance level in any bridge arm is around 100 kilohms. Although this is somewhat higher than has been traditional in many Wheatstone bridges, it is quite practical in view of modern insulating materials. This higher level greatly reduces series resistance effects due to switch contacts and wiring and makes possible higher resistance measurements.

Detectors usually have a fixed input resistance where as it is quite easy to provide generators with widely varying output resistances. For this reason the bridge was designed to look like a fairly constant 100 kilohms to the detector, which is a reasonable level for the detector to work at; while the resistance the generator sees varies from 1 ohm to 100 kilohms.

3.2 GENERATOR-DETECTOR ISOLATION

Either the generator or the detector for the MODEL 230B RESISTANCE BRIDGE may be grounded but the other must be well isolated from ground. The leakage resistance from the isolated unit to ground can appear across a 100 kilohm internal bridge arm. In view of the 0.01% accuracy specification of the bridge, this means the leakage resistance must be in excess of 10^{10} ohms before it can be considered as causing an insignificant error. However, this is not a sufficient definition of the magnitude of leakages that may be encountered in generators used with this bridge. In particular, the situation can exist when using a voltage divider, limiting resistor, or multi-voltage generator where voltages within the generator circuit are higher than the voltage applied to the bridge terminals, see Fig. 3.1.

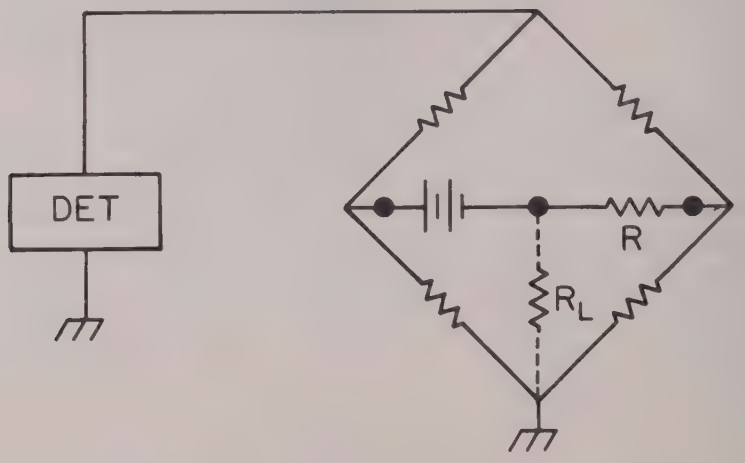


Fig. 3.1

The effect of this condition will be to magnify the error due to any leakage resistance that might exist between the generator terminals (those terminals of the generator circuit that are at a higher potential than the GEN terminals of the bridge) to the ground corner of the bridge. This condition can be prevented by use of a guarded generator such as the ESI MODEL 800 DC GENERATOR DETECTOR and connecting the guard chassis of the generator to one of the generator corners of the bridge. A guarded generator may readily be obtained by means of a battery with the necessary divider and limiting resistors all mounted on a guard chassis suitably isolated from

ground (greater than 10^{10} ohms), see Fig. 3.2. The guard chassis should then be connected to one of the generator corners of the bridge.

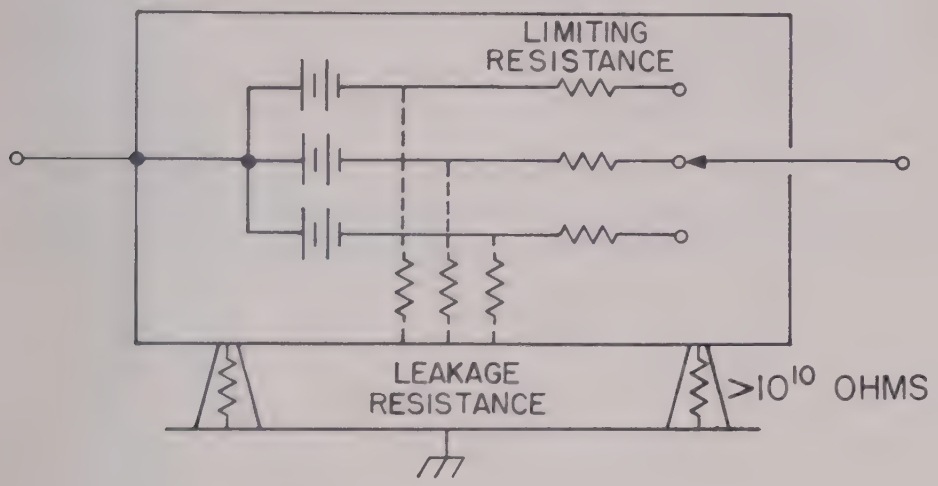


Fig. 3.2

Thus, leakage resistances which are driven by higher voltage sections of the generator network will cause current to flow to the guard electrode rather than returning it through the bridge arms. A line powered generator should only be used if all the requirements mentioned above for battery powered supplys are met and in addition the line transformer provides sufficient isolation. A further requirement of adequate filtering must also be imposed if a modulator type detector is to be used.

3.3 GROUNDING THE BRIDGE

It is advisable that the bridge always be grounded rather than floating. If the bridge is floating it is very difficult to determine what effects the leakage resistances are having on the measurement. By proper grounding, however, the effects not only can be determined but minimized as well. Generally, the DET 1 terminal is the most desirable corner of the bridge to have grounded. For all conditions, however, the basic rule is to ground the corner that is adjacent to the two lowest resistance bridge arms.

While it is important that the bridge be grounded, it is equally important that it be grounded at one point only. Multiple grounds are very likely to cause errors due to ground loop currents.

3.4 GENERATOR-DETECTOR INTERCHANGABILITY

The resistance of the bridge looking in at the detector terminals is a fairly constant 100 kilohms while that at the generator terminals varies widely. Though the generator and detector may be interchanged, the usual procedure will be to connect them as indicated on the bridge panel. This will usually provide the best impedance matching since the impedance of most detectors is fixed while that of the generator can readily be varied to provide the bridge with the proper amount of power.

> NOTE: The maximum power that should ever be applied to the MODEL 230B is one watt. (See Par. 2.12 GENERATOR REQUIREMENTS.)

3.5 DESIGN FEATURES

3.5.1 SWITCH CONTACT RESISTANCE

A number of features have been incorporated in the MODEL 230B RESISTANCE BRIDGE which contribute to its accuracy and convenience. Of particular note is the elimination of switch contact and wiring resistance as sources of error. In more conventional Wheatstone bridges, it is often found that at some place within the operating range of the bridge, the resistance of the switch contacts becomes a significant part of one of the ratio arms of the bridge. In the 230B this effect has been reduced to a negligible value by a very effective arrangement of the ratio arm resistors (see Fig. 3.5).

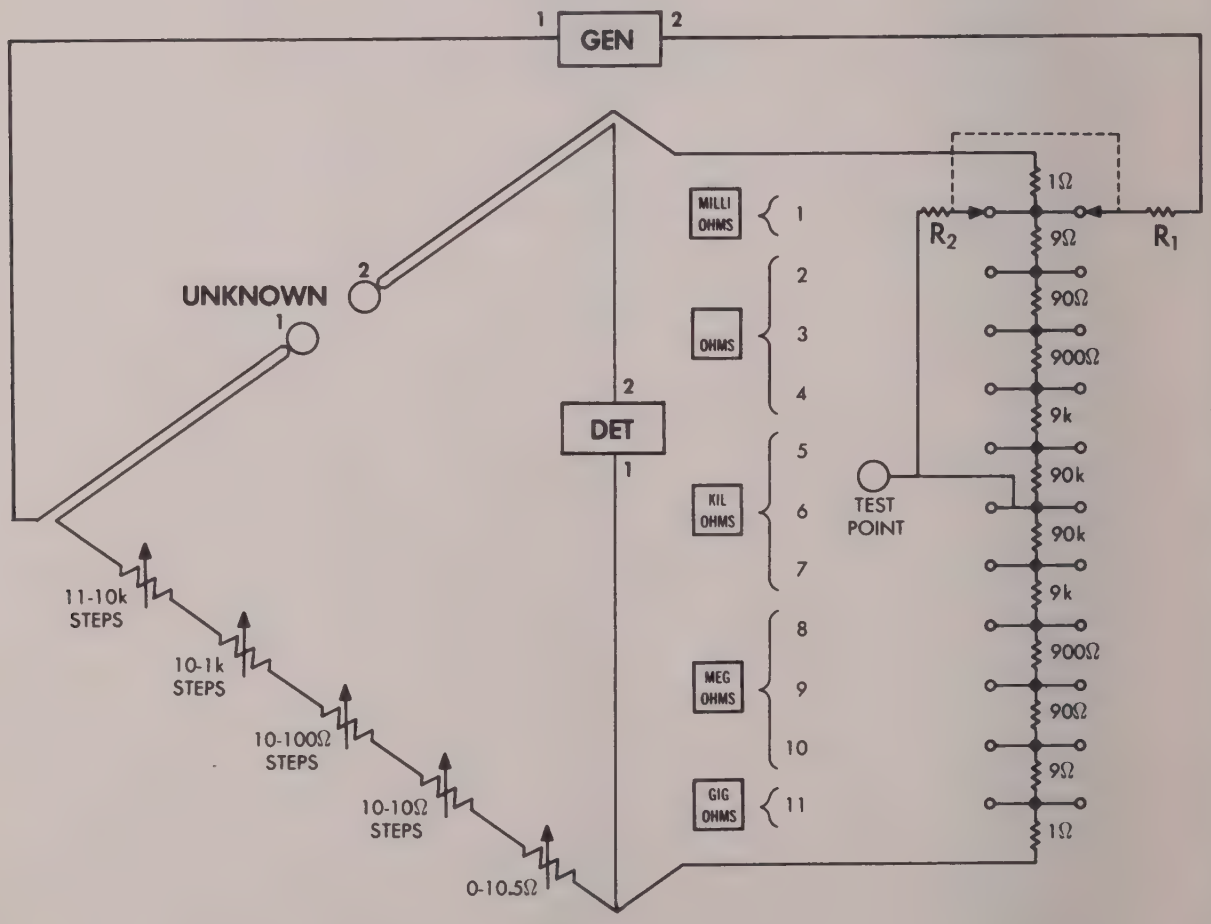


Fig. 3.5

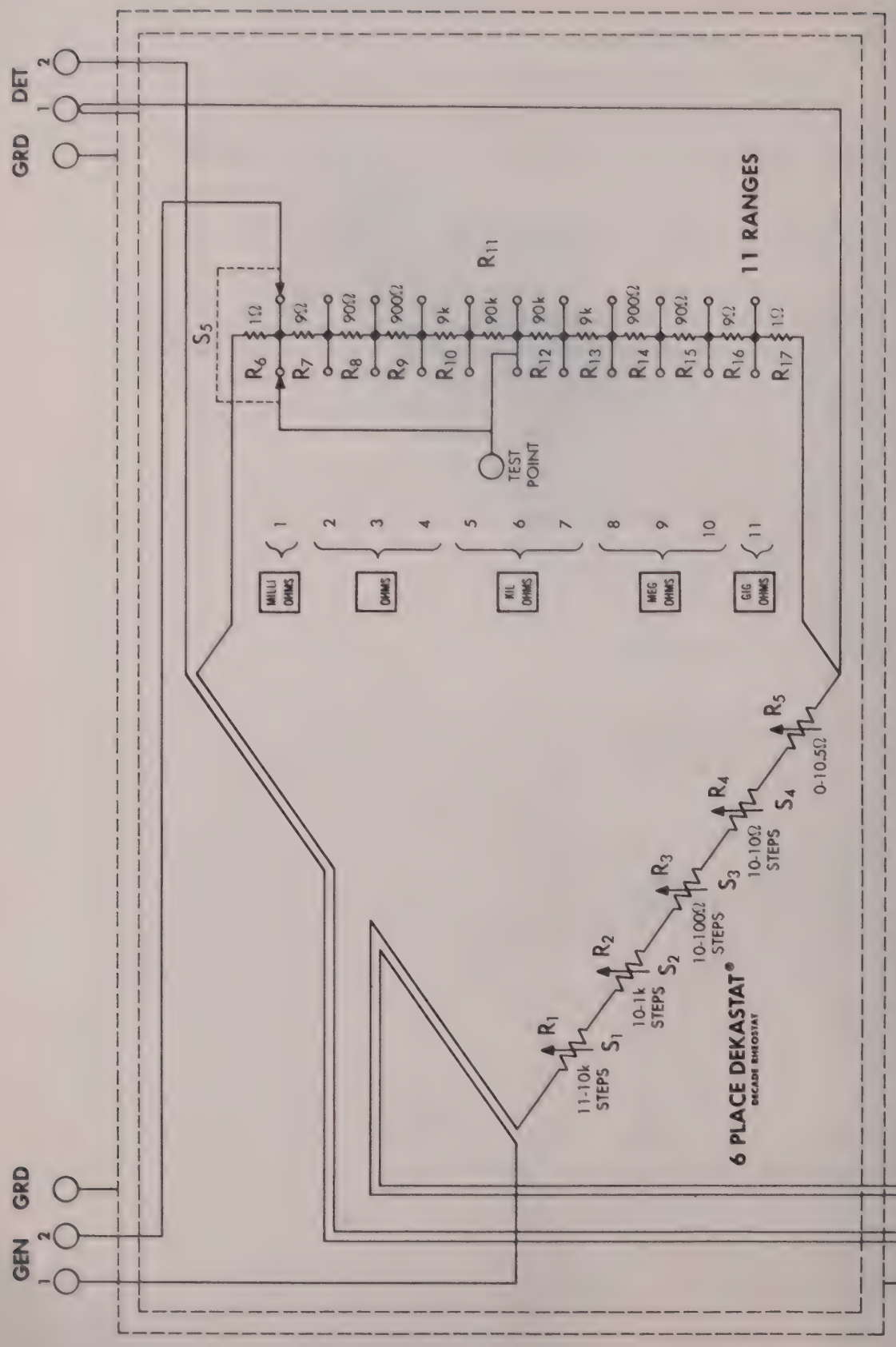
The ratio arm resistors are permanently connected together. The range switch is a double pole switch that switches the generator and a potential tap along the string. As is shown in Figure 3.5, the contact resistance R_1 is in series with the generator and will have no affect on the accuracy of the bridge. The contact resistance R_2 which is less than 10 milliohms will always be in series with 100 kilohms so that is can be neglected.

3.5.2 INTERNAL WIRING RESISTANCE

The junctions of all connections to the UNKNOWN terminals have been made directly at the binding posts. This places a minimum of wiring resistance in series with the resistor to be measured. Instead the wiring resistance is in series with the generator, detector, decade resistance arm and one of the ratio arms. The only one of these resistances that is apt to be a problem is the one in series with the ratio arm since the resistance of this ratio arm can be as low as one ohm. During manufacture, however, this resistance is made as low as possible and then included in the adjustment and calibration of the ratio arm.

3.5.3 INTERNAL GUARDING

The ESI MODEL 230B RESISTANCE BRIDGE utilizes a Wheatstone bridge connected so that the resistor being measured is guarded from internal bridge leakages. The bridge is enclosed in a guard chassis which is connected to the DET 1 corner of the bridge. Any leakage resistance from the UNKNOWN 1 corner of the bridge to the guard appears across the detector. Leakage resistance from UNKNOWN 2 appears across the decade resistance arm whose maximum resistance is 100 kilohms. This in terms of the 0.01% accuracy specification of the bridge means that this leakage resistance must be in excess of 10^{10} ohms before its effect can be neglected.



MODEL 230B CIRCUIT DIAGRAM

SECTION IV
MAINTENANCE

4.1 PREVENTIVE MAINTENANCE

The following procedures should be performed periodically to insure maximum accuracy and reliability from the ESI Model 230B Resistance Bridge.

If the maintenance procedures outlined in the following paragraphs indicate the need for major repairs, it is recommended that the unit be sent to the factory for service and repair. Our Service Department will be glad to furnish necessary repair information as well as any replacement parts. Unauthorized repairs will invalidate our warranty. If the instrument is more than one year old, a reasonable charge may be expected for replacement parts or for complete reconditioning if the instrument is returned to the factory.

4.1.1 CHASSIS AND DUST COVER REMOVAL

a) Remove the two mounting screws from the rear of the dust cover.

b) Gently lift chassis from dust cover and place on a clean surface. CAUTION: DO NOT TOUCH OR REST UNIT ON RESISTORS.

4.1.2 VISUAL INSPECTION

Inspect the unit for possible circuit defects. These defects may include such things as loose or broken connections, damaged binding posts, and scorched wires or resistors. For most visual troubles, the remedy is apparent; however, particular care must be taken when heat-damaged components are detected. Overheating of components is often the result of other, less apparent defects in the circuit. It is essential that the cause of overheating be determined before replacing heat-damaged components.

4.1.3 CLEANING AND LUBRICATION

Clean the front panel with a clean rag soaked in mild solvent. The rheostat of the decade resistance arm is the only internal component which requires cleaning and lubrication. Clean and lubricate rheostat as follows:

CAUTION: Do not use solvent on the rheostat. Solvents will leave a residue which may affect its performance.

a) Polish the contact surfaces lightly with abrasive cloth (Crocus cloth or equivalent).

b) Remove loose particles by wiping with Nylon cloth.

c) Apply a liberal amount of pure petroleum jelly to the contact surfaces.

4.1.4 CHECKING THE DIAL SETTINGS

In order to check that the dials are in their proper position with respect to the switch shaft, the following procedure is recommended:

Resistance Dials:

1) Attach an ohmmeter between the UNKNOWN 2 and DET 1 terminals.

2) Turn the extreme left-hand resistance dial counter clockwise through all positions and check that the position giving the lowest reading is the zero position.

3) Follow the same procedure as above for the remaining three resistance dials.

Range Dial:

1) Attach an ohmmeter to the UNKNOWN 1 and the GEN 2 terminals.

2) Turn the range dial through all eleven positions and check that the position giving the lowest ohmmeter indication is the MILLIOHM position.

4.2 TROUBLE-SHOOTING

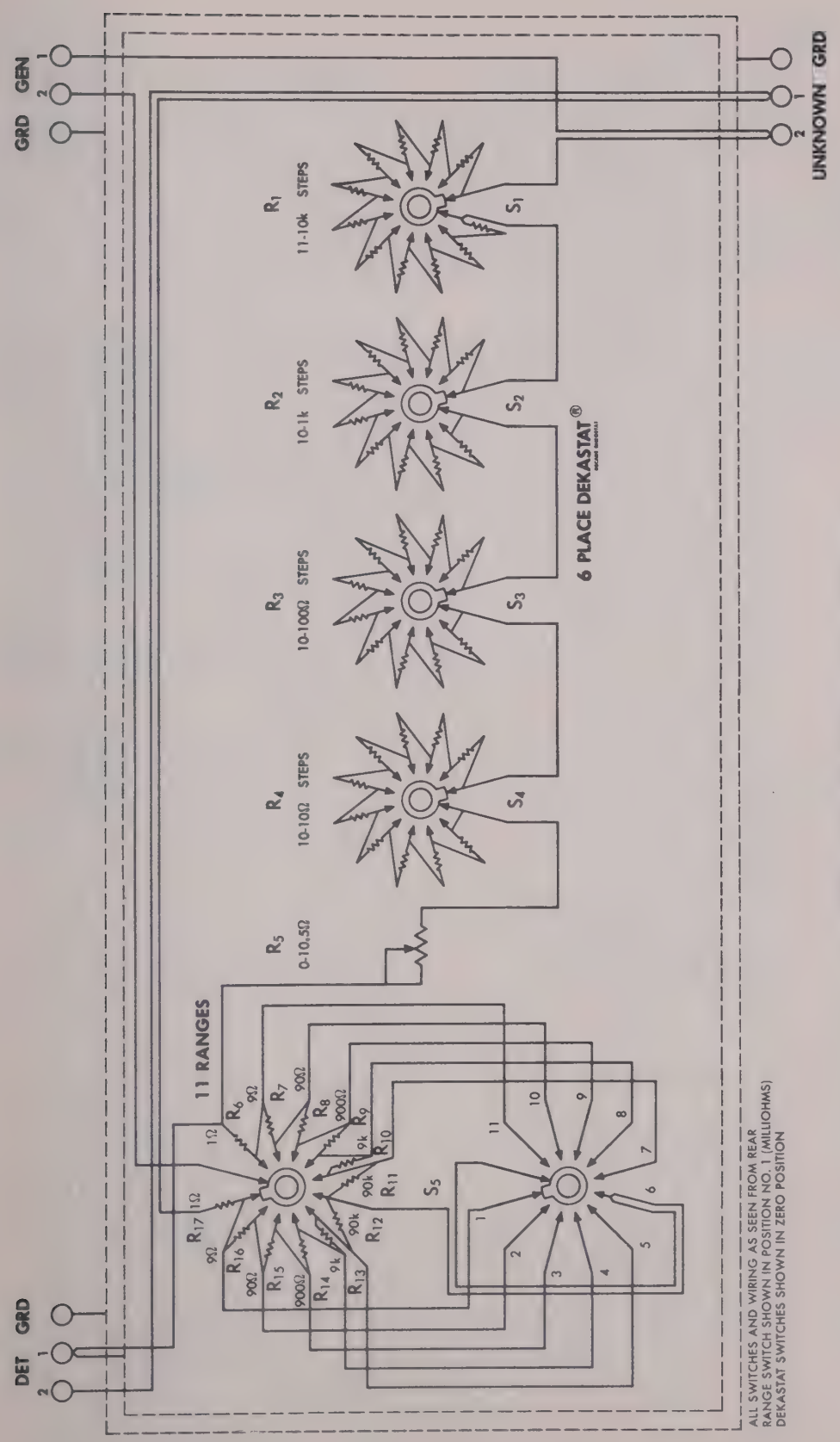
The following table lists various abnormal indications, probable causes and corrective procedures for the MODEL 230B RESISTANCE BRIDGE. Troubles may be located quickly by first performing a basic measurement (Section II) to aid in localizing the trouble, then refer to the following table and component location illustrations (Par. 4.3 and Fig. 4.1). Calibrate the system after any repair or replacement is performed. (See Section V CALIBRATION and ADJUSTMENT for recommended procedures).

4.2.1 TEST EQUIPMENT AND TOOLS REQUIRED

Test Equipment and Tools	Use
A Wheatstone bridge	For accurate resistance measurements.
Laboratory resistance standards	For checking accuracy of resistance dial indications.
A screw driver	To remove bridge from dust cover.
Allen-head wrenches, #8 hexagon	To loosen or tighten set screws.

4.2.2 TROUBLE-SHOOTING CHART

Symptom	Probable Cause	Procedure
Bridge	Loose or improper external connections	Check all binding post connections.
	Generator or detector	Check operation of generator and detector.
	Internal bridge trouble	See below.
Questionable or erratic operation	Faulty wiring	Check wiring to be sure that no short circuits exist.
	Faulty switch	Check all switches for proper contact and operation.
	Defective resistor	Test resistors for continuity and approximate rated values.
	Faulty decades	Check decades for continuity and for approximate resistance values corresponding to settings of the decades.
Readings inaccurate	Dials in wrong position on shaft.	Check dial location on shaft. See Par. 4.1.4 CHECKING THE DIAL SETTING.
	Defective resistors	Check resistors for continuity and accuracy.
	Calibration and/or adjustment	Recalibrate unit as instructed in Section V, CALIBRATION AND ADJUSTMENT.



MODEL 230B WIRING DIAGRAM

4.4 PARTS LIST

The following parts list is in alpha-numerical order of the circuit reference designator. Miscellaneous parts are included at the end of the list. Manufacturer of the part is given in a code number according to the Federal Supply Code for Manufacturers; see list of manufacturers below. Parts recommended as spare parts to sustain operation in isolated locations are indicated in the recommended spare parts column.

Parts manufactured by Electro Scientific Industries must be ordered from the factory. When ordering parts from the factory, include the following information:

Model and serial number of the instrument
Electro Scientific Industries part number
Circuit reference designator
Description of part

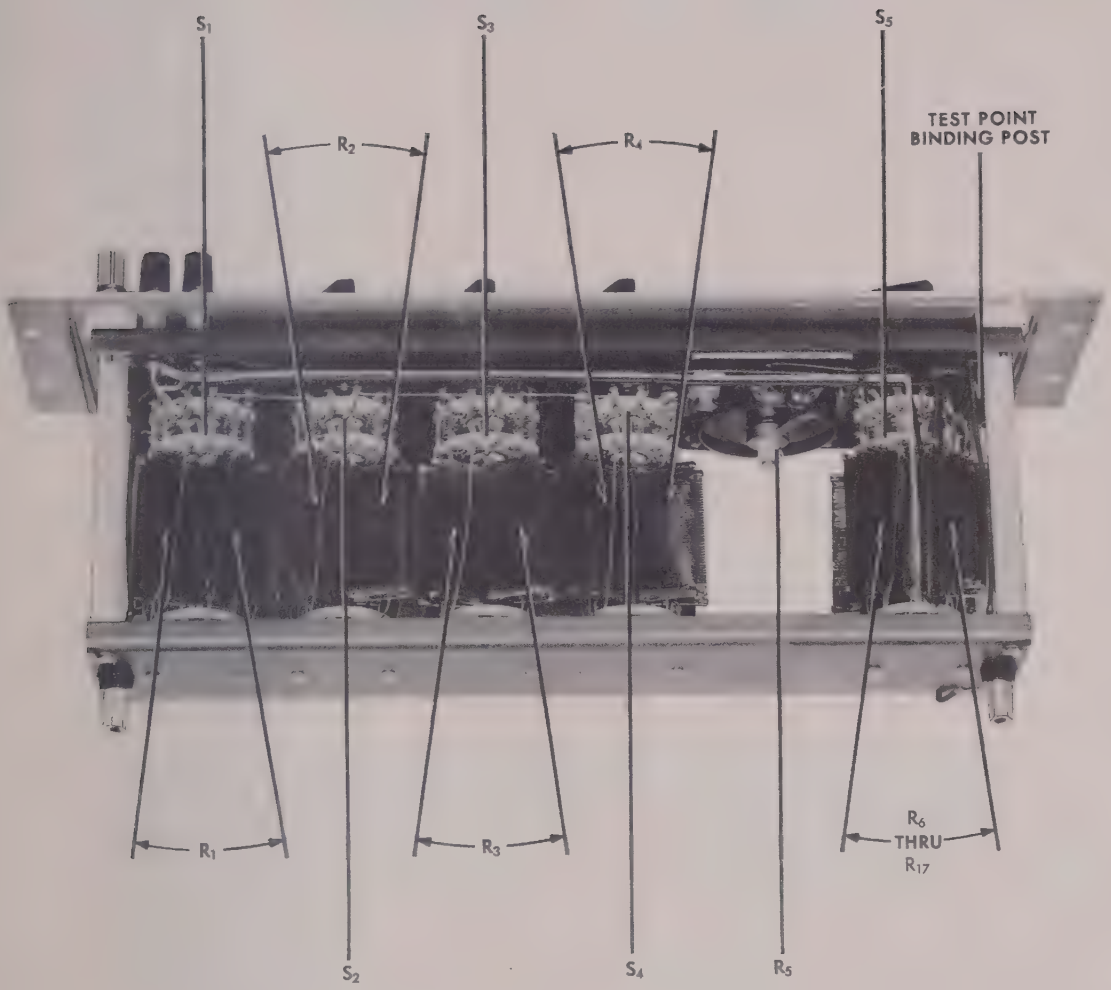
CODE LIST OF MANUFACTURERS

11837 ELECTRO SCIENTIFIC INDUSTRIES
Portland, Oregon

Ckt Ref	Description	Mfr	ESI Part No.	Qty Used	Recm SP
A_1	Switch Assy, 1st	11837	2361	1	
A_2	Switch Assy, 2nd	11837	2363	1	
A_3	Switch Assy, 3rd	11837	2364	1	
A_4	Switch Assy, 4th	11837	8653	1	
A_5	Range Res, Switch Assy	11837	2337	1	
R_1	Res, Fxd, Precision, 10k, Part of Assy A_1	11837	2365	10	
R_2	Res, Fxd, Precision, 1k, Part of Assy A_2	11837	2366	10	
R_3	Res, Fxd, Precision, 100Ω, Part of Assy A_3	11837	2367	10	

Ckt Ref	Description	Mfr	ESI Part No.	Qty Used	Recm SP
R_4	Res, Fxd, Precision, 10Ω, Part of Assy A_4	11837	8433	10	
R_5	Rheostat, 0-10.5Ω	11837	8655	1	
R_6	Res, Fxd, 1Ω, Part of Assy A_5	11837	2368	1	
R_7, R_{16}	Res, Fxd, 9Ω, Part of Assy A_5	11837	2370	2	
R_8, R_{15}	Res, Fxd, 90Ω, Part of Assy A_5	11837	2371	2	
R_9, R_{14}	Res, Fxd, 900Ω, Part of Assy A_5	11837	2372	2	
R_{10}, R_{13}	Res, Fxd, 9k, Part of Assy A_5	11837	2373	2	
R_{11}, R_{12}	Res, Fxd, 90k, Part of Assy A_5	11837	2374	2	
R_{17}	Res, Fxd, 1Ω, Part of Assy A_5	11837	2369	1	
S_{1-4}	Switch, 12 position	11837	8825	4	
S_5	Switch, Range Res	11837	8826	1	
	MISCELLANEOUS				
	Knob (Rheostat Assy)	11837	1271	1	
	Knob	11837	1266	5	
	Binding Post Cap, Insulated	11837	1170	6	2
	Binding Post Cap, Metal	11837	1172	3	1
	Binding Post	11837	4235	8	

Ckt Ref	Description	Mfr	ESI Part No.	Qty Used	Recm SP
	Binding Post (Unknown 1)	11837	4234	1	
	Slider Assy	11837	8622	1	
	Reversing Drive Assy	11837	8817	1	


S1
S3
S5
TEST POINT
BINDING POST
R2
R4
R1
R3
R6
THRU
R17
S2
S4
R5

SECTION V
CALIBRATION AND CONTROL

5.1 INTRODUCTION

This section provides MODEL 230B RESISTANCE BRIDGE calibration procedures for those who have the necessary facilities. Calibration should be performed in a laboratory environment. If this is not possible, return the instrument to the factory or to an authorized service facility for calibration.

The MODEL 230B RESISTANCE BRIDGE is carefully tested and calibrated prior to shipment to insure that it conforms to published specifications. However, calibration should be performed periodically (always after repair or replacement of components) to maintain performance specifications at all times.

The following procedures are listed in a recommended sequence for a complete calibration operation. All test equipment used and controls not mentioned in a particular step should remain as instructed in the previous steps.

5.2 TEST EQUIPMENT REQUIRED

Test Equipment	Description
*Four terminal resistance bridge	Capable of measuring 1 ohm to 100 kilohms with a resolution of 0.001% and accurate to 0.01%
Laboratory resistance standards	1 ohm thru 1 megohm in powers of 10 known to within ± 0.005%

*Such as the ESI MODEL 242 RESISTANCE MEASURING SYSTEM.

5.3 PROCEDURE

5.3.1 CALIBRATION OF DECADE RESISTANCE ARM

1. Set the resistance reading dials to 0.	Range setting does not matter.
2. Measure zero resistance of decade resistance arm.	Measure from UNKNOWN 2 terminal to DET 1 terminal. Should be less than 40 milliohms.
3. Measure resistance at 10 div. points on rheostat and at every step on the preceeding decades.	These readings should be within ± (0.005% + 1 dial div) of their nominal value after substracting the zero resistance.

5.3.2 CALIBRATION OF RATIO ARMS

1. Connect a current lead of the four terminal resistance bridge to GEN 2 and the corresponding potential lead to the TEST POINT binding post. (See Fig. 5.1).	The four terminal resistance bridge used must be capable of seeing ± 0.001% from 1 ohm to 100 kilohms. ESI MODEL 242 RESISTANCE MEASURING SYSTEM or equivalent.
2. Connect the other current lead to DET 2 and the corresponding potential lead to UNKNOWN 1.	Set range dial to position 1. These will be the RATIO ARM A resistors.
3. Measure ratio resistors corresponding to range switch positions 1 through 6.	The first resistor will be nominally 1 ohm and each succeeding resistor will be up by a factor of 10.
4. Reconnect the current and potential leads of step 2 to DET 1 and UNKNOWN 2 respectively. Set the resistance reading dials to 0.	These will be RATIO ARM B resistors.

5. Measure ratio resistors corresponding to range switch positions 6 thru 11.

The resistance corresponding to position 6 will nominally be 100 kilohms and will decrease by a factor of ten for each succeeding range position.

NOTE: While it is essential that the ratio of the resistors of RATIO ARM A to the 100 kilohm ratio resistor of RATIO ARM B be within ± 0.005% of nominal, it is not necessary that the resistors themselves be within a tight tolerance of their nominal value. Likewise for the ratio of the resistors of RATIO ARM B to the 100 kilohm resistor of RATIO ARM A.

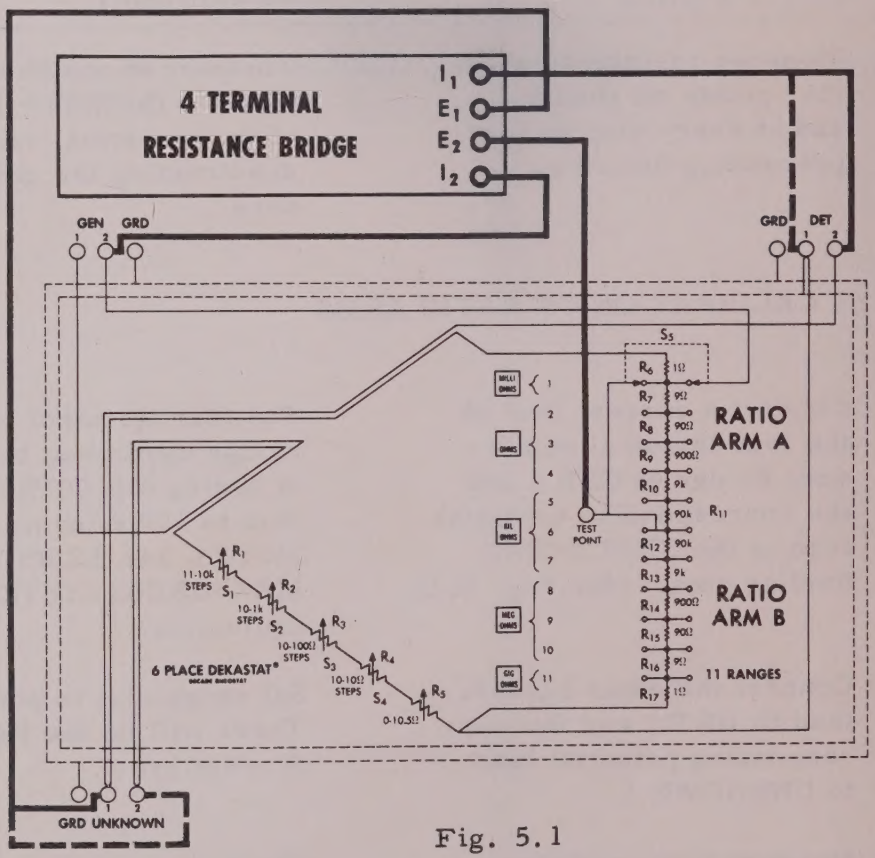


Fig. 5.1

5.3.3 FUNCTIONAL TEST

Measure laboratory resistance standards. Subtract zero and lead resistance from measured value for all standards below 1 kilohm. It is recommended that the functional test be made for the seven lowest range positions (1 ohm through 1 megohm).

All readings after correction for zero and lead resistance should be within ± (0.01% + 1 dial div.) of the value of the standards.

MP MASTER
MA30711